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AN OPTIMIZATION OF PROCESS PARAMETERS FOR STIR CAST ALUMINIUM METAL MATRIX COMPOSITES TO IMPROVE MATERIAL REMOVAL RATE

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ABSTRACT

The aim of this effort is to examine the development of stir casting on the aluminum metal matrix composite (MMC). The Taguchi L9 experimental technique is chosen to erect the quantities of machining tests. Abrasive Water Jet Machining is utilized to perform the machining on the stir casted aluminium MMCs. ANOVA analyzes the variety of process parameters and their property of the MMC for increasing Material Removal Rate (MRR). The result shows that the medium water pressure (2750 bar), average traverse speed (30 mm/min) and high abrasive flow rate (80 g/mm) are the influential process parameters to machining the aluminium metal matrix composites. The optimal values for SR are water pressure of 2300 bar, traverse speed of 25 mm/min and abrasive flow rate of 80 g/mm.

KEYWORDS: Dissimilar Alloys, Welding Speed, Feed, Tilt Angle, Taguchi Approach & ANOVA Analysis

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Original Article

INTRODUCTION

Metal Matrix Composites (MMCs) has promising advantages in the automotive and space craft industries due to the characteristics such as enhanced module, weight, toughness, rigidity, wear strength and corrosion résistance. In particular, Aluminum Metal Matrix Composites (AMMCs) encounter the particular application as control rods in the nuclear power industry and automotive industry as heavy duty structural parts. The AMMC's superior characteristics lacked prevalent alloys. MMCs are versatile and superior performance materials with industrial purposes that are increasing for eternity. The MMCs' characteristics and arrangement can be modified according to the industrial demand and applications. In the manufacture and machining of these MMCs, process systems coddled magnetize the scientists and the industrial community. MMC process capability relies on the materials selected, their characteristics, distributions and interface between them [1]. The impact of cutting circumstances (cutting speed and feed) and cutting time on turning MMCs was researched. For MMCs, unconventional machining is more reliable. It offers superior precision in the machining of geometrically complicated forms [2].

Abrasive Water Jet Machining (AWJM) is one of the most quickly advancing and intensively studied material machining or cutting processes in the unconventional machining method. It is commonly used to cut various kinds of broad range of building materials, metals, fiberglass, rubber, stone and plastics. This method requires less cutting power and a mild heat-affected area [3,4]. The AWJM method was used for machining the hardest materials. It operates on the basis of a tight, concentrated water jet blended with abrasive particles, leading

in extremely high speeds that remove the metal surface when it impacts the work piece. Parameters of machining are based on machine economy and machining quality. The study of regression is used to examine the impact on MMCs of machining process parameters. The removal rate of material and surface roughness are the key considerations for optimizing AWJM's process parameters [5]. The roughness of the surface is most influenced by the transverse rate and the standoff distance in the AEJM [6].

The parameters were optimized using an orthogonal Taguchi array technique and the variance analysis (ANOVA) was used to examine the cutting features of MMCs [7]. AWJM's process parameter is optimized to machine the green composites using the response surface methodology (RSM). The experiments are performed based on the construction of the Box–Behnken and optimal parameters are selected by multi-response optimization via desirability. The pressure, distance of standoff and velocity of the nozzle are chosen as the parameters of control. The roughness of the surface and handling time are chosen as parameters of the reaction. ANOVA is used to determine the significant parameter of the optimization developed [8]. To explore the process parameters of Abrasive Water Jet Turning (AWJT) on 96 percent alumina ceramic, the RSM and discrete method with face-centered central composite design were used. And to find the optimum process, the quadratic form of RSM associated with the Sequential Approximation Optimization method is used [9].

By analyzing the variance, the primary impacts of parameters and their interaction between them were evaluated and the reaction surfaces for MRR were acquired to match a polynomial function of the second order. Cut depth and traverse velocity have been found to be the most important parameters, while rotational speed is irrelevant. Furthermore, the studies indicate that there are important interactions on MRR between traverse velocity and stress, abrasive mass flow rate and cut depth, and pressure and cut depth. A complete model discussion has been reported drawing interesting considerations on the AWJT process characterizing phenomena, where parameters interactions play a fundamental role [10,11]. In this work, through the stir casting method, the workpiece is manufactured and AWJM method machined the alloy. The investigation's objective is to maximize the rate of material removal using Taguchi technique.

EXPERIMENTAL PROCEDURE

Stir casting technique produces the job piece material aluminium metal matrix. Due to its simplicity, flexibility, homogeneous particle dispersion and low cost mass production, the stir casting method was regarded. AWJM machines the stir cast aluminium metal matrix. The input parameters were the water pressure, abrasive flow rate, water pressure and traverse velocity. The reaction parameters were regarded to be the material removal rate (MRR). Holes with a diameter of 6 mm were generated on the metal matrix surface. The surface roughness tester is used to measure the surface roughness (taylsurf SJ – 201). The process parameter levels have been listed in the Table 1.

Table 1: Range of Process Parameter

Levels	Water Pressure (bar)	Transverse Speed	Abrasive Flow Rate (g/mm)
1	2500	20	40
2	2750	30	60
3	3000	40	80

RESULTS AND DISCUSSIONS

Taguchi Parametric Optimization for MRR

The responses such as MRR of the holes is determined for each experiment and recorded in Table 2. The Taguchi method was used to obtain ideal parametric combinations to obtain maximum material extraction rate. This method can be used to deliver required quality depending on experiment design [12,13]. Using this technique, system design and parametric design were efficiently accomplished. Any issue optimization can be readily solved by Taguchi-based experiment design [14, 15].

Signal to Noise (S/N) Ratio Analysis for MRR

The tests were conducted on the basis of the orthogonal array that reduced the amount of tests. All experimental findings were converted into a proportion of signal to noise. The performance individuality differences from the required values were effectively evaluated by this proportion. The response output relies primarily on the S/N ratio, whether it can be maximum and minimum [15]. Higher quantity of material removal rate and minimum was regarded in this experiment and tabulated in Table 3.

The most important and contribution parameter was discovered on the basis of variance assessment. Table 4 displays the outcome of ANOVA for MRR. Water pressure is the dominant variable that impacts the answers from variance analysis.

Table 2: Range of Process Parameters and its MRR

Levels	Water Pressure (bar)	Traverse Speed (mm/min)	Abrasive Flow Rate (g/mm)	MRR (g/min)
1	3000	40	30	10.35
2	3000	30	40	8.45
3	2500	30	30	13.48
4	2750	40	40	12.69
5	3000	20	80	15.61
6	2750	20	30	11.96
7	2500	40	80	17.48
8	2500	20	40	15.79
9	2750	30	80	19.26

Table 3: Mean of S/N Ratio for MRR

Level	Water Pressure (bar)	Traverse Speed (mm/min)	Abrasive Flow Rate (g/mm)
1	7.927	10.297	9.98
2	11.95	9.263	12.14
3	13.253	10.89	11.98
Delta	3.51	1.753	1.68
Rank	1	2	3

Table 4: ANOVA Analysis for Water Pressure, Transverse Speed and Abrasive Flow Rate

Source	DF	Adj. SS	Adj. MS	F-value	P-Value
Water pressure	2	21.8	11.6	10.22	0.082
Traverse speed	2	4.99	7.61	2.59	0.29
Abrasive flow rate	2	4.68	2.69	2.47	0.35
Error	2	2.22	1.01		
Total	8	33.62			

S=3.022, R-sq=84.72 %, R-sq (adj)=88.27 %

Contour Plot Analysis for Material Removal Rate

Contour plot is employed to discover the impact of two different process parameters on the responses (material removal rate). The contour plot analysis for material removal rate versus traverse speed, abrasive flow rate are shown in Figure 1. The higher amount of material removal rate is attained at the medium value of traverse speed, abrasive flow rate.

The contour plot assessment for material removal rate versus water pressure and abrasive flow rate is provided in Figure 2. At low water pressure value and elevated abrasive flow rate, the higher quantity of material removal rate is achieved.

The contour plot assessment for material removal vs water pressure, abrasive flow rate is provided in Figure 3. At low water pressure and average abrasive flow rate, the higher quantity of material removal rate is achieved.

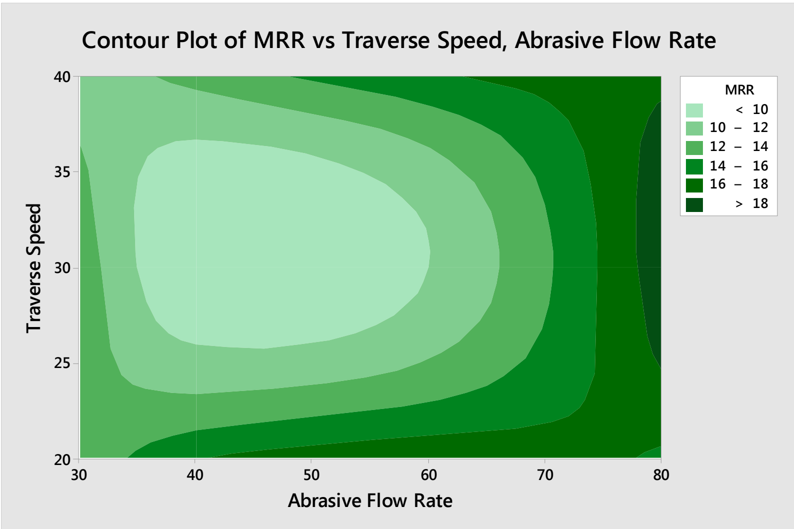

Figure 1: Material Removal Rate vs Traverse Speed, Abrasive Flow Rate.

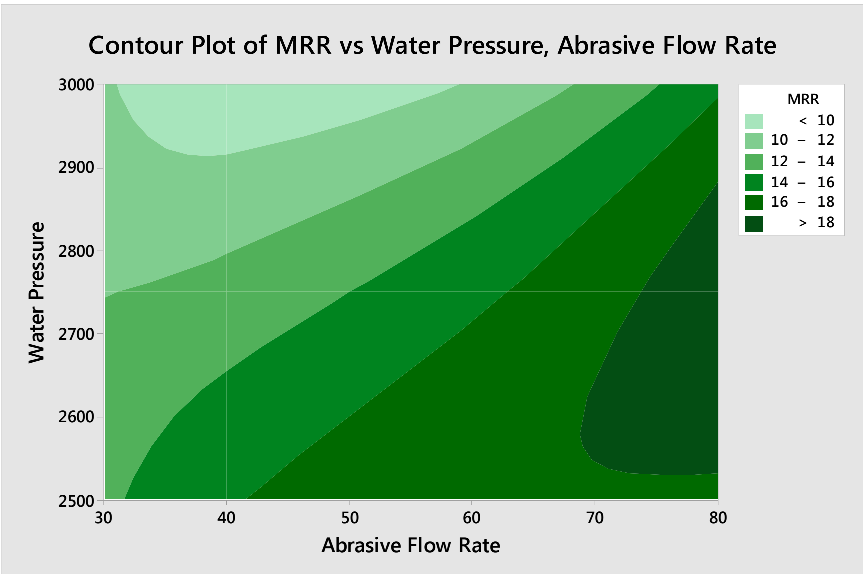

Figure 2: Material Removal Rate vs Water Pressure, Abrasive Flow Rate.

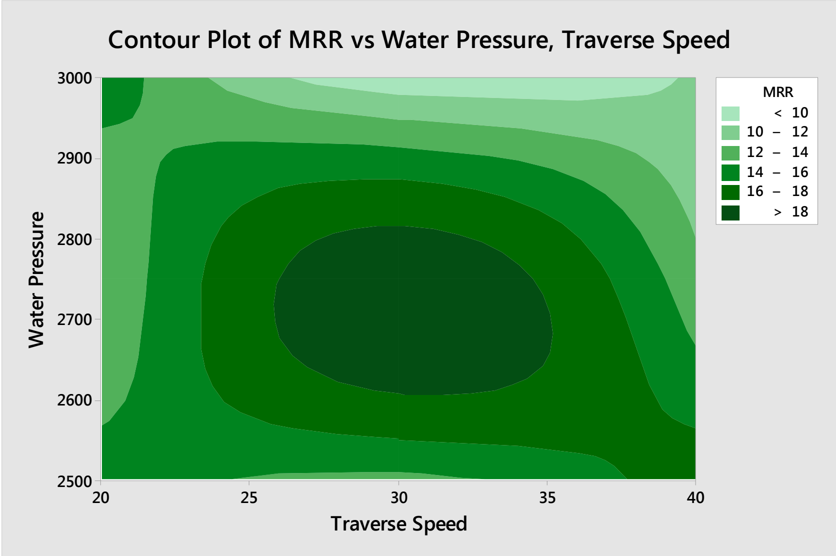

Figure 3: Material Removal Rate vs Water Pressure, Transverse Speed.

Taguchi Parametric Optimization for SR

The surface roughness of the holes is measured for each trial and noted in Table 5. The Taguchi parametric optimization method was utilized to obtain the ultimate parametric combinations to get maximum minimum roughness of the surface.

Signal to Noise (S/N) Ratio Analysis for SR

On basis of the orthogonal array, the tests were carried out, which minimized the number of assessments. All experimental results were transformed into a ratio of signal to noise. This percentage efficiently assessed the performance individuality differences from the necessary values. The reaction output mainly depends on the proportion S/N, whether it can be minimum and maximum. In this experiment, a lower amount and minimum of surface roughness was considered and compiled in Table 6.

Table 5: Range of Process Parameters and its SR

Levels	Water Pressure	Traverse speed	Abrasive Flow Rate	SR
1	3000	40	30	3.39
2	3000	30	40	2.61
3	2500	30	30	1.96
4	2750	40	40	4.28
5	3000	20	80	5.19
6	2750	20	30	3.71
7	2500	40	80	2.29
8	2500	20	40	1.52
9	2750	30	80	1.29

Table 6: Mean of S/N Ratio for SR

Level	Water Pressure (bar)	Traverse Speed (mm/min)	Abrasive Flow Rate (gm/mm)
1	2.671	3.349	2.863
2	4.391	3.09	2.712
3	1.67	2.295	3.142
Delta	2.583	1.010	0.41
Rank	1	2	3

Based on the variance evaluation, the most significant and commitment parameter was found. Table 7 shows ANOVA's results for SR. Water pressure is the dominant variable affecting the response from the evaluation of variance.

Table 7: ANOVA Analysis for Water Pressure, Transverse Speed and Abrasive Flow Rate

Source	DF	Adj. SS	Adj. MS	F-value	P-Value
Water pressure	2	11.1472	5.542	16.67	0.057
Traverse speed	2	1.756	0.916	2.76	0.266
Abrasive flow rate	2	0.282	0.149	0.45	0.690
Error	2	0.657	0.3347		
Total	8	13.893			

S=3.001, R-sq=84.69 %, R-sq (adj)=88.19 %

Contour Plot Analysis for Surface Roughness

Contour plot is a visual methodology of conspiring steady z pieces, called contours, on a 2-dimensional configuration to serve a 3-dimensional surface. In other words, provided a value for z, lines were drawn to link the coordinates (x, y) where the z value happens. Contour plots are accessible in certain numerical software applications for particular purposes. They are also accessible in many geometry and mathematics initiatives for general purposes. Many include a simple contour chart over a rectangular map whereas others allow filled or shadowed contours to be colored. Contour plot is used to detect the effect on the answers (surface roughness) of two distinct process parameters. The contour plot analysis shows the abrasive flow rate for roughness of the surface versus traverse speed in Figure 4. The minimum surface roughness is registered at the water pressure from 2500 bar to 2900 bar and at lower traverse speed. The lower amount of surface roughness is attained at lower value of traverse speed and water pressure.

The contour plot assessment for surface roughness versus water pressure and abrasive flow rate is provided in Figure 5. The lower surface roughness is recorded at lower water pressure with all the abrasive flow rates. The lower surface roughness is recorded at higher water pressure and medium abrasive flow rate.

The contour plot evaluation is given in Figure 6 for surface roughness vs water pressure, abrasive flow rate. At low abrasive flow rate and average traverse speed, the lower quantity of surface roughness is registered.

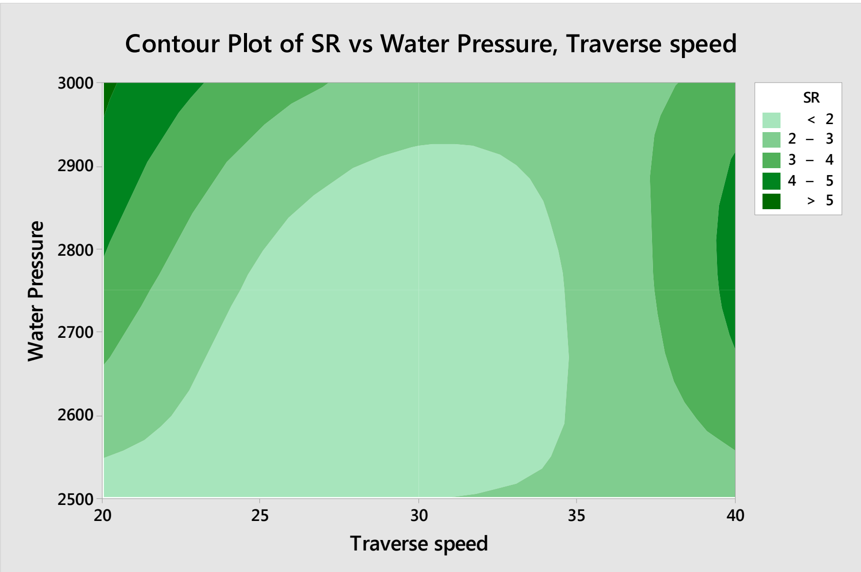

Figure 4: Surface Roughness vs Water Pressure, Traverse Speed.

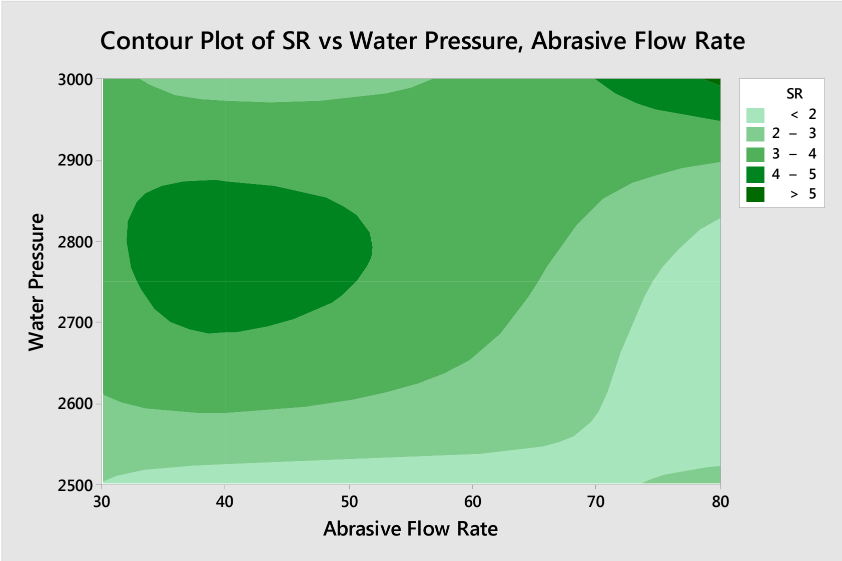

Figure 5: Surface Roughness vs Water Pressure, Abrasive Flow Rate.

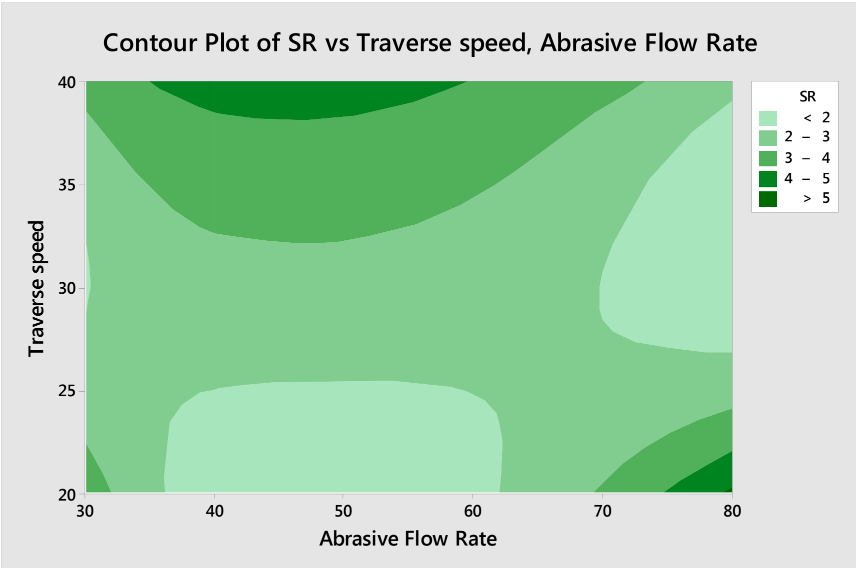

Figure 6: Surface Roughness vs Traverse Speed, Abrasive Flow Rate.

CONCLUSIONS

In this research, the aluminium metal matrix composite is developed by stir casting. The experimental method Taguchi L9 orthogonal is utilized to form the number of machining experiments. Using the AWJM remove the material from the MMCs for optimizing the process parameters with the help of abrasive particles. ANOVA experimentation analysis is carried out in order to obtain the most suitable (optimum) range of selected parameters and their results on the material removal rate of aluminium metal matrix composites. The result illustrates that the medium water pressure (2750 bar), average traverse speed (30 mm/min) and high abrasive flow rate (80 g/mm) are the influential process parameters to machining the aluminium metal matrix composites. The lower values for SR are water pressure of 2300 bar, Traverse speed of 25 mm/min and abrasive flow rate of 80 g/mm.

REFERENCES

1. *Sidhu, S. S., Batish, A. and Kumar, S. 2013. Fabrication and electrical discharge machining of metal–matrix composites: A review. Journal of Reinforced Plastics and Composites, 32 (17), pp.1310-1320.*

2. *Bains, P. S., Sidhu, S. S. and Payal, H. S. 2015. Fabrication and Machining of Metal Matrix Composites: A Review. Materials and Manufacturing Processes, 31 (5), pp. 553-573.*

3. *Begic-Hajdarevic, B., Cekic, A., Mehmedovic, M. and Djelmic, A. 2015.'Experimental study on surface roughness in abrasive water jet cutting. Procedia Engineering, 100, pp. 394–399.*

4. *Cojbasic, Z., Petkovic, D., Shamshirband, Sh., Wen Tong, Ch., Sudheer, Ch., Jankovic, P., Ducic, N. and Baralic, J. 2016. Surface roughness prediction by extreme learning machine constructed with abrasive water jet. Precision Engineering, 43, pp. 86–92.*

5. *Aultrin, K. S. J. and Anand, M. D. 2014. Optimization of machining parameters in AWJM process for an copper Iron alloy Using RSM and regression analysis. International Journal of Emerging Engineering Research and Technology, 2 (5), pp. 19-34.*

6. *Sharma, M. K., Chaudhary, H. and Kumar, A. 2017. Optimization of abrasive waterjet machining process parameters on aluminium AL - 6061. International Journal of Science and Research, 6(6), pp. 869-874.*

7. *Davim, J. P.2002. Design of optimisation of cutting parameters for turning metal matrix composites based on the orthogonal arrays. Journal of Materials Processing Technology, 132, pp. 340-344*

8. *Jagadish, A. R., Bhowmik, S. and Ray, A. 2016. Prediction and optimization of process parameters of green composites in AWJM process using response surface methodology, The International Journal of Advanced Manufacturing Technology, 87(5-8), pp.1359-1370.*

9. *Yue, Z., Huang, C., Zhu, H., Wang, J., Yao, P. and Liu, Z. W. 2014. Optimization of machining parameters in the abrasive water jet turning of alumina ceramic based on the response surface methodology, The International Journal of Advanced Manufacturing Technology, 71, pp. 2107 – 2114.*

10. *Shunmugasundaram, M. and Maneiah, D. 2018. Wastage minimization and manufacturing cost reduction in raw edge cogged belts by lean manufacturing method, International Journal of Mechanical Engineering and Technology, 9 (7), pp.678-686.*

11. *Zohourkari, I., Zohoor, M. And Annoni, M. 2015. Investigation of the effects of machining parameters on material removal rate in abrasive waterjet turning, Advances in Mechanical Engineering, Article ID 624203, pp. 1-11.*

12. *Idu, M. A. C. D. O. N. A. L. D., Erhabor, J., Timothy, O., & Ovuakporie-Uvo, O. (2014). Market survey and heavy metal screening of selected medicinal plants sold in some markets in Benin City, Nigeria. International Journal of Humanities, Arts, Medicines and Sciences, 2, 7-16.*

13. *Izquierdo, B., Sánchez, J. A., Plaza, S., Pombo, I. and Ortega, N. 2009. A numerical model of the EDM process considering the effect of multiple discharges, International Journal of Machine Tools & Manufacture, 49(3), pp.220-229.*

14. *Shunmugasundaram, M., Praveen Kumar, A. and Maneiah, D. 2019. An experimental analysis and process parameter optimization on friction stir welded dissimilar alloys, International Journal of Mechanical and Production Engineering Research and Development, 9(2), pp.407-414.*

15. *Singh, R. B. P., Singh, A., & Choudhary, S. K. Surface Mining and Heavy Metal Pollution of Waterand Soil: A Case Study in Simlong Coalfield in Sahebganj District, Jharkhand.*

16. *Pal, D., Bangar, A., Sharma, R. and Yadav, A. 2012. Optimization of grinding parameters for minimum surface roughness by Taguchi parametric optimization technique, International Journal of Mechanical and Industrial Engineering, 1 (1), pp. 74-78.*
17. *Rao, M. S., Ravinder, S. and Kumar, A. S. (2014) 'Parametric optimization of abrasive water jet machining for mild steel : Taguchi Approach', International Journal of Current Engineering and Technology, 1 (1), pp. 28–30.*
18. *Shunmugasundaram, M., Maneiah, D. and Koora, R. 2018. Design and implementation of cellular manufacturing system in medium scale industry by traditional methods, International Journal of Mechanical Engineering and Technology, 9(8), pp. 565-574.*
19. *Kumar, R. S. (2015). Latent heat storage material evaluation base on AHP and TOPSIS for low temperature solar heating applications. International Journal of Mechanical and Production Engineering Research and Development, 5(1), 73-82.*